(12) UK Patent Application (19) GB (11) 2 371 910 (13) A

(43) Date of A Publication 07.08.2002

(21) Application No 0102434.8

(22) Date of Filing 31.01.2001

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(51) INT CL^7
H05B 33/12

(52) UK CL (Edition T)
G5C CA342 CA361 CHE

(56) Documents Cited
EP 0978889 A1

(58) Field of Search
UK CL (Edition S) G5C CHE
INT CL^7 G02F 1/1343 , G09G 3/32 , H05B 33/08 33/12 33/14
ONLINE DATABASE: EPODOC, JAPIO, WPI

(54) Abstract Title
Display devices

(57) The invention provides a display device 26 including a plurality of discrete display segments 2. Each display segment 2 is provided with a passive addressing array of anode electrodes 6 and cathode electrodes 10. Drive circuits 14 and 18 are provided for the anode and cathode electrodes and these are arranged within the display area of each display segment. The display area of each segment comprises display elements arranged between the passive array of anode electrodes 6 and the passive array of cathode electrodes 10. The display elements are organic light emitting diodes (OLED) and may comprise organic polymer material or small molecule material. By interconnecting a number of display segments, a large area display can be achieved without the requirement for a passive addressing array with long electrode lengths. This reduces the electrical resistance and parasitic capacitance of the passive addressing array, enabling the display to provide improved luminance in a displayed image and to operate at higher speeds, providing improved resolution.

Fig.9.

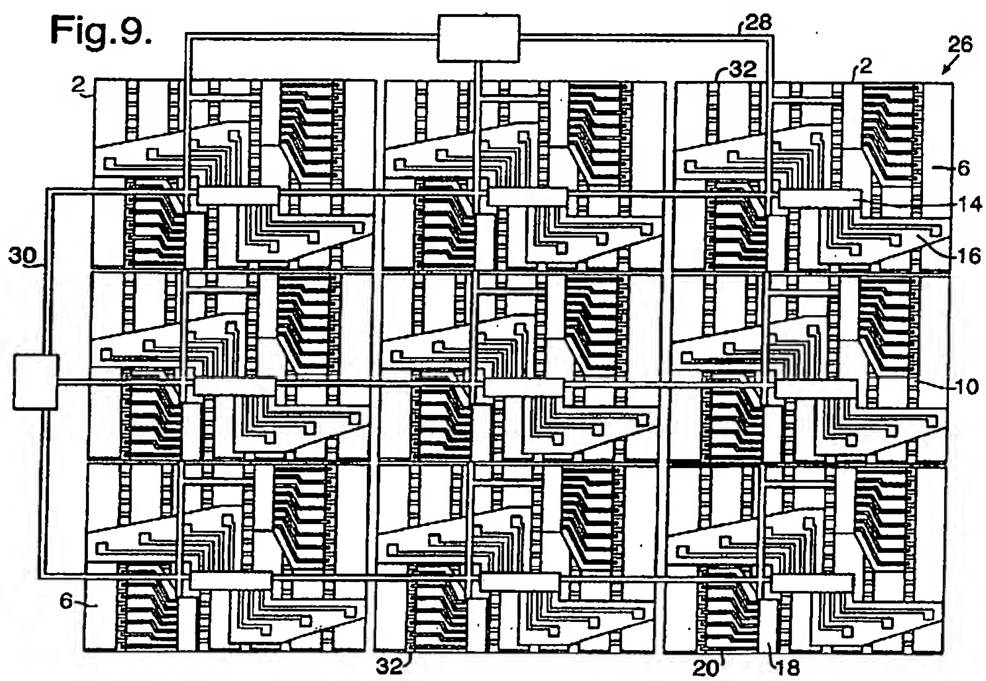

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Fig.1.

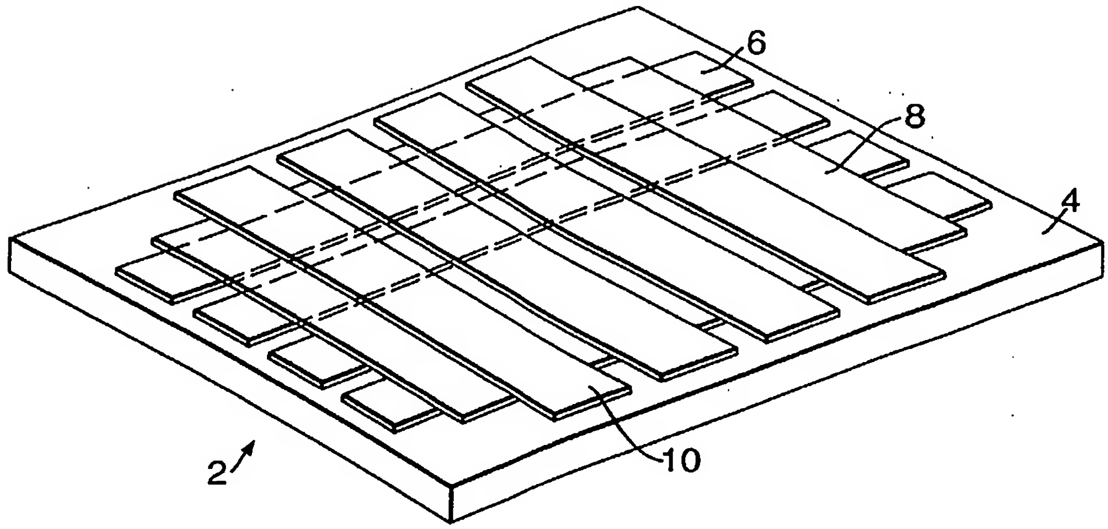

6
8
4
2
10

Fig.2.

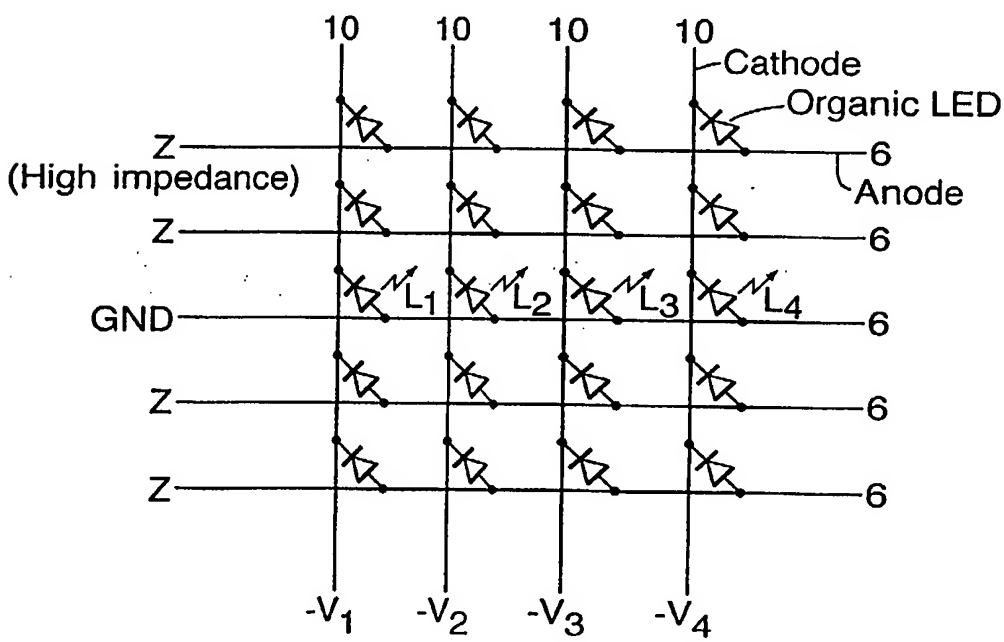
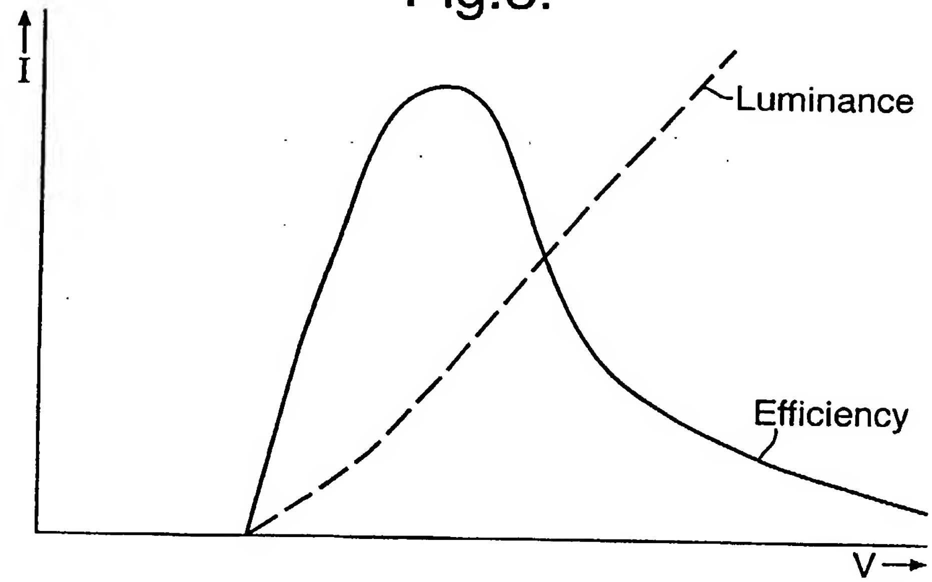
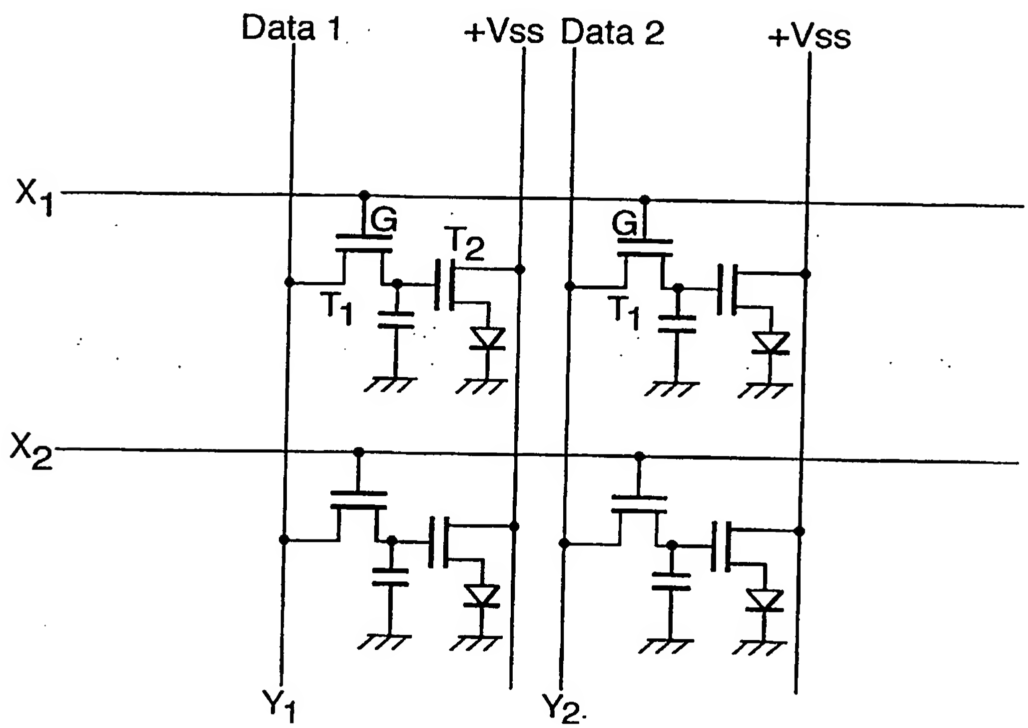

10
10
10
10
Cathode
Organic LED
Z
(High impedance)
6
Anode
Z
6
GND
L_1
L_2
L_3
L_4
6
Z
6
Z
6
$-V_1$
$-V_2$
$-V_3$
$-V_4$

Fig.3.



I
Luminance
Efficiency
V

Fig.4.



Data 1
+Vss
Data 2
+Vss
X_1
X_2
G
T_2
T_1
G
T_1
Y_1
Y_2

Fig.5.

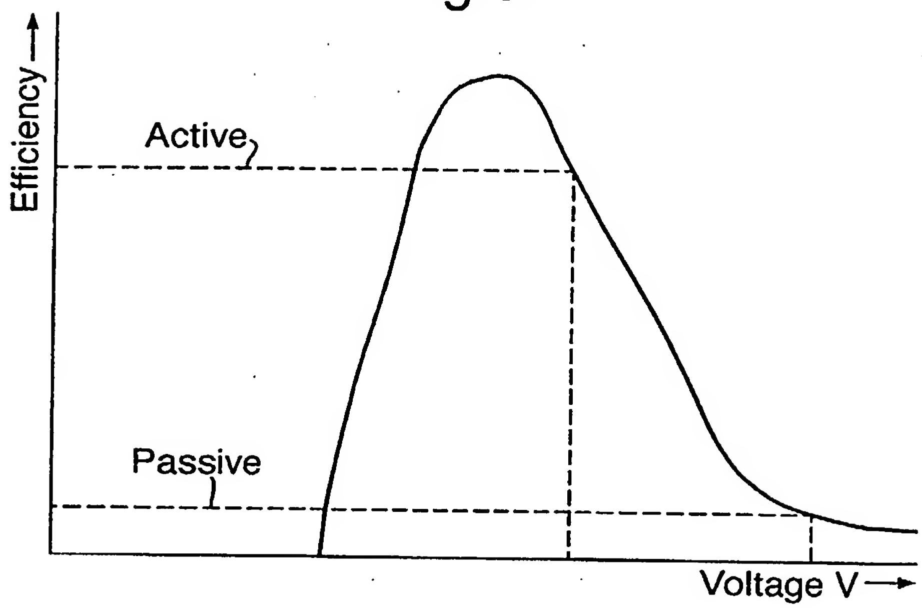


Fig.6.

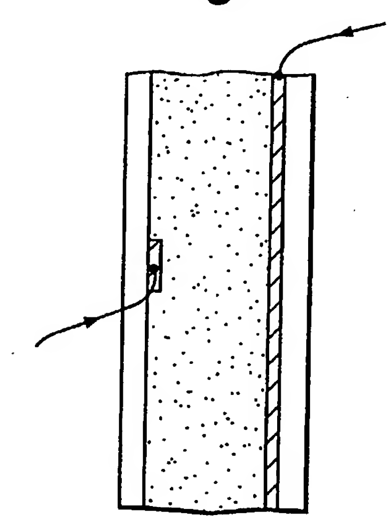


Fig.7.

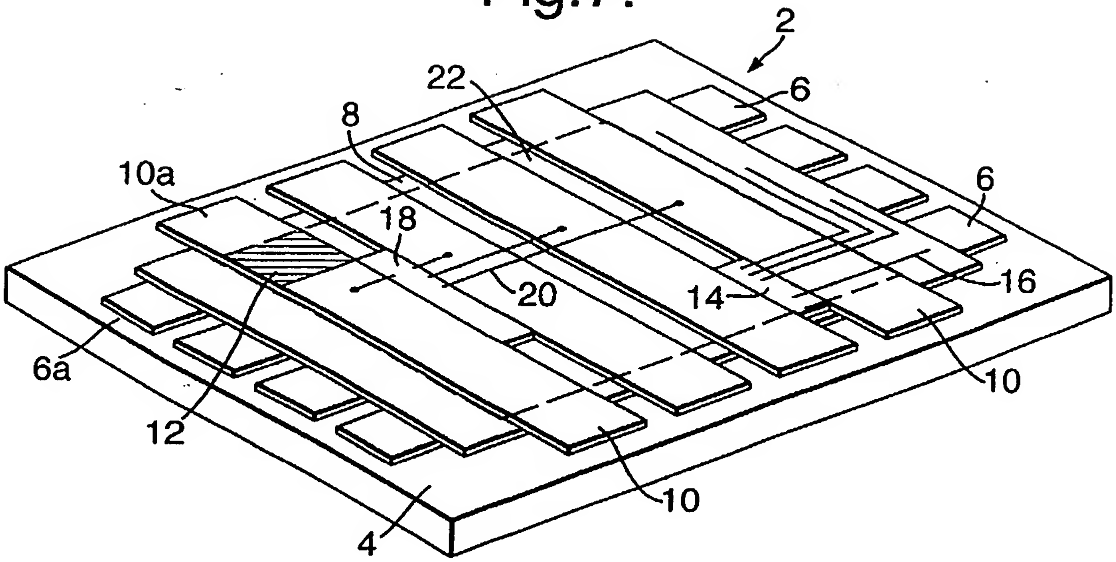
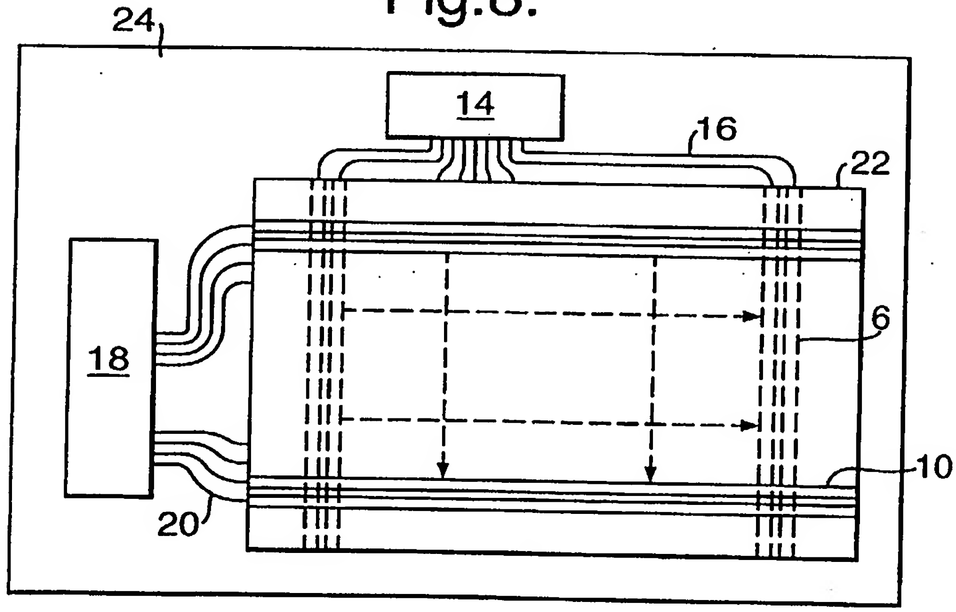


Fig.8.



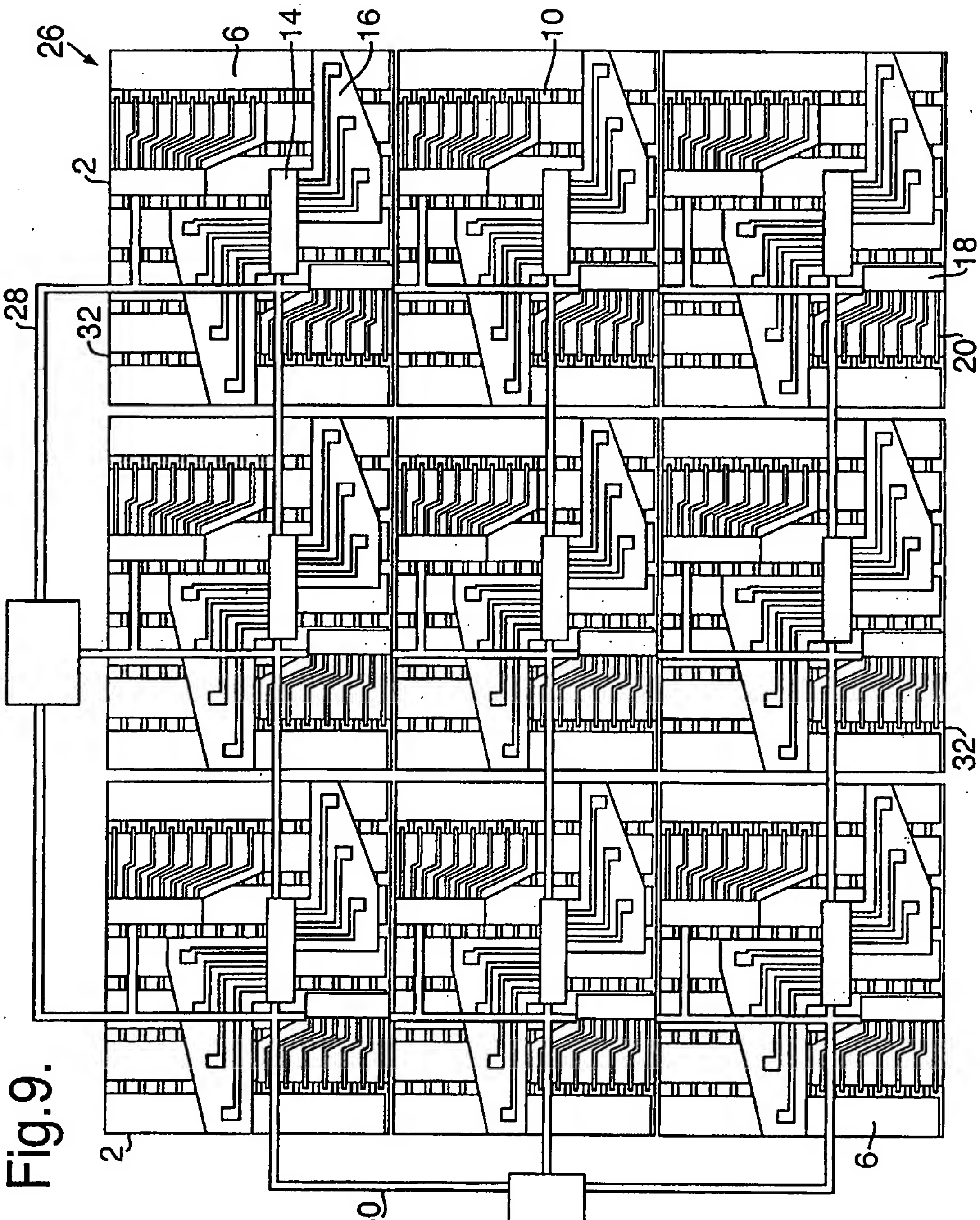


Fig.9.

Fig.10.

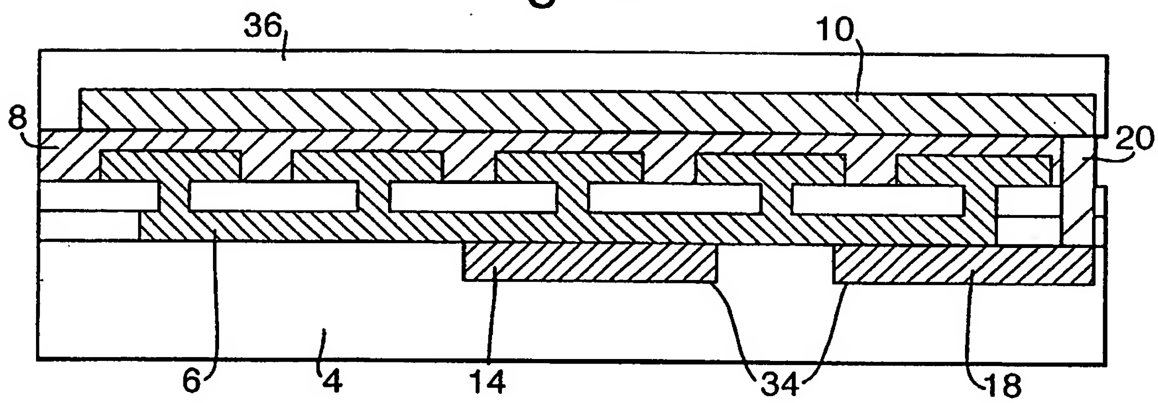
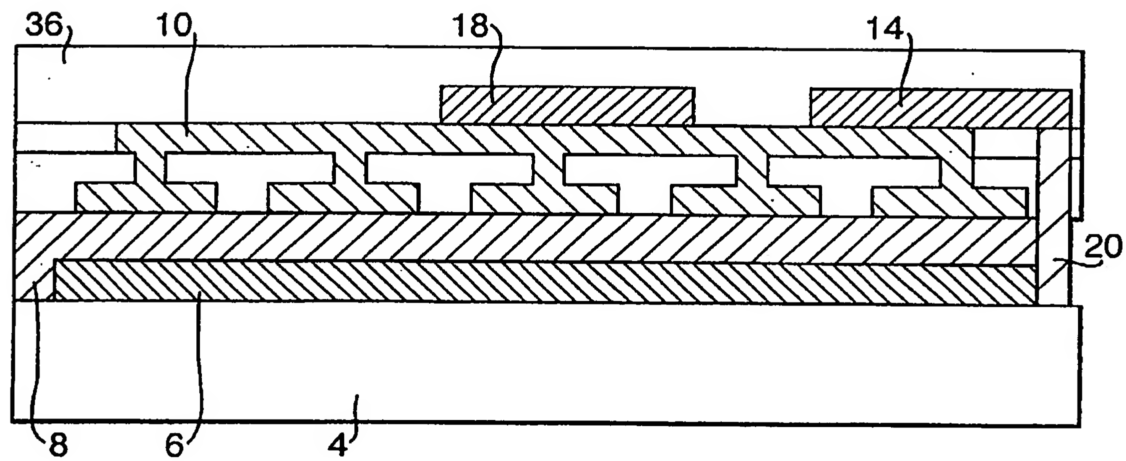


Fig.11.



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DISPLAY DEVICES

The present invention relates to display devices and, in particular, to driver arrangements for display devices.

A variety of display devices, such as liquid crystal displays or light emitting diode (LED) displays, are in widespread use. Recently, a further type of LED display has been proposed in the form of an addressable electroluminescent display. The electroluminescent display device comprises a mix of organic materials such as organic polymers or small molecule polymers sandwiched between an anode and a cathode supported by a solid substrate, such as, for example, a glass, plastics or silicon substrate, the organic materials providing the light emitting elements of the display.

Organic material LED's have a much sharper response characteristic than liquid crystal display devices. The organic LED devices have very sharp 'turn-on' and 'turn-off' characteristics in response to an applied current which provides such displays with improved contrast in comparison to liquid crystal displays. In addition to improved contrast, the organic materials are also considered to provide significant benefit in terms of fabrication.

For organic LED displays incorporating organic polymer materials as the light emitting pixels, the organic polymer materials may be deposited on the substrate using fabrication techniques which cannot be adopted to manufacture liquid crystal or conventional light emitting diode displays. One method which has been proposed is to deposit the organic polymer materials onto the substrate using inkjet printing in which the polymer materials are deposited as discrete drops of the material onto predisposed deposition sites provided as a matrix configuration on the substrate. The use of inkjet printing can be particularly advantageous for colour displays because the various organic polymer materials which comprise the red, green and blue LED's at each pixel of the display can be deposited in the required predefined patterns without the need for any etch process steps.

Furthermore, as the active materials of the display are organic polymer materials, they may be deposited onto any suitable substrate material, including plastics materials in the form

of a continuous, flexible and spoolable sheet. The characteristics of the organic polymer materials lend themselves, therefore, to the fabrication of very large area monochrome or colour display devices containing very large numbers of rows and columns of the pixels of active material making up the display area of the display device.

An organic polymer electroluminescent display may be driven using either an active or a passive matrix addressing system. The display elements which create the light output at any pixel of the display are, in essence, provided by organic polymer light emitting diodes. These are current driven devices, so when an active matrix addressing scheme is used to address the display to create a displayed image, two transistors per pixel of the displayed image are provided, the first to act as a switch so as to allow a data signal to be passed to a second transistor which acts as a current driver for the LED of the pixel, thereby to determine the brightness for the pixel.

A passive matrix addressing scheme is shown schematically in Figure 1. The display element 2 shown in Figure 1 comprises a substrate 4 supporting an array of strip-shape electrodes 6 which constitute the anode electrodes of the display element. A layer 8 of an organic photoemissive material is provided over the anode electrodes 6 and a second array of strip-shape electrodes 10, which constitute the cathode elements for the display element, are provided over the photoemissive layer 8. It can be seen from Figure 1 that the respective arrays of anode and cathode strip-shape electrodes 6, 10 are arranged substantially orthogonal to each other. If a voltage is applied between any two of the strip-shape electrodes, a current will pass through that part of the photoemissive layer 8 arranged in the area where the two electrodes overlap. The material of the photoemissive layer behaves as a light emitting diode, and hence that part of the photoemissive layer in the overlap area of the two electrodes to which the voltage is applied will emit light. This can be seen more clearly with reference to Figure 2.

From Figure 2 it can be seen that the pixels of the display are each made up of an organic LED coupled between respective strip-shape anode and cathode electrodes. The strip-shape anode electrodes are, for example, decoupled from ground potential by a high impedance circuit, indicated by a value Z in Figure 2. Data signals, indicated by voltages V_1 to V_4 in Figure 2, are applied to the cathode electrodes of the array. At the same time, the

strip-shape anode electrodes are selectively coupled directly to ground potential. Hence, for the example shown in Figure 2, when the voltage V_1 is applied to the left most strip-shape cathode electrode, the organic LED L_1 will emit light. Likewise, when voltages V_2 to V_4 are applied to the cathode electrodes 10, the LED's L_2 to L_4 will respectively emit light.

Addressing schemes of the above type are called passive matrix schemes because there are no active elements located within the display area to drive the LED's to emit light. The light emission results purely from the data signals, in the form of voltage pulses, provided from the frame or boundary area of the display device to one of the sets of strip-shape electrodes, either the cathode or anode electrodes. However, the thin strip-shape electrodes have electrical resistance, and this electrical resistance becomes larger with increase in the length of the strip-shape electrodes. Hence, if the size of the display area of the display device is made larger, the length of the strip-shape electrodes increases and, it follows, that the electrical resistance of the strip-shape electrodes is also increased.

The displays are driven from the side edge of the display and hence, when a voltage pulse is applied to any particular electrode, the voltage actually applied to the pixels underlying that electrode will decrease with the distance of any pixel from the edge of the display to which the voltage pulse is applied due to the electrical resistance of the electrode. It will be appreciated, therefore, that if the electrodes are relatively long, the voltage applied to a pixel located at the distal end of the electrode relative to the driven edge, will be significantly less than the voltage applied to a pixel located close to the driven edge. The brightness of the display decreases therefore with increase in distance from the driven edge, giving rise to non-uniform brightness of displayed image.

Additionally, the intensity of the light emitted from an LED display is a function of the peak illumination intensity of the individual LED devices and the number of lines of pixels in the actual display area of the display. This is because the LED's of the display are addressed by pulse operation in a frame period. The time period during which any LED may be addressed is known as the duty ratio and is equal to t_f/N, where t_f is the frame period and N is the number of lines in the display. It follows, therefore, that if the number of lines in the display is increased, the duration for which any pixel may be addressed is decreased. The peak intensity of luminance from an LED occurs when it is addressed and this is averaged

over the frame period. Therefore, to provide a flicker-free display, as the size of the display area is increased, and the number of lines in the display also increases to maintain resolution, the peak intensity of light emitted from the LED devices must be compensated to maintain a required output intensity for the display because it is only possible to address the LED devices for a shorter duration during a frame cycle. The peak intensity of the LED devices can be increased by increasing the voltage of the pulses used to address the LED devices. It can be appreciated, therefore, that as display size is increased, relatively high voltage pulses are required to drive the LED devices and provide sufficient light output intensity from the display. This is a considerable disadvantage, especially when the display is incorporated in a device powered from an internal battery supply, such as a laptop computer. However, the use of such relatively high voltage pulses gives rise to further problems concerning operation of the LED's.

It is known that in LED devices, the possibility of recombination of electron-hole pairs, which produces the light emission, can decrease with an increase in voltage. This is because the optimum region for operation of a LED device is what is commonly known as the 'recombination zone'.

The operational characteristic of a typical LED is shown in Figure 3, which shows how luminance and device efficiency vary in relation to the current and voltage applied to the device. It can be seen from Figure 3 that, once a current threshold is reached, as the current passing through the device is increased, the luminance of the device also increases. However, with regard to efficiency, it can be seen that device efficiency peaks very quickly once the device starts to emit light. With further increase in voltage applied to the device, the efficiency falls quickly to a relatively low efficiency level, as shown in Figure 3. For organic polymer LED's the peak efficiency occurs typically in the range of about 2.2V to about 5V, whereas, when the applied voltage is in the range of about 10V to 20V, the efficiency of the device has fallen back to such a low level that it becomes inefficient to use such LED's. Device efficiency is a key issue for many practical applications of LED displays as the equipment incorporating the display is frequently required to operate from an internal battery source.

This sharp decrease in device efficiency arises because, as the voltage applied between the anode and cathode for a LED is increased, the recombination zone migrates towards one of the device electrodes. Because, the shape of the recombination zone depends on the applied voltage, with passive matrix addressed displays it becomes increasingly difficult to provide sufficient display light output intensity because relatively high voltage pulses are required to drive the LED devices, which, in turn, means that the LED devices can no longer be operated in the optimum recombination zone and, therefore, at an acceptable level of efficiency.

To summarise therefore, display devices typically contain more than 200 lines in order to provide sufficient resolution in the displayed image. Therefore, the LED's have a relatively low duty ratio which is compensated by increasing the voltage applied to the LED's. However, this gives rise to lower operating efficiency of the LED's, which in turn decreases the luminance of the LED's, as shown by Figure 5. These two operational difficulties are inter-related and compound each other and, furthermore, they increase disproportionately with an increase in the number of lines in the display.

Active matrix addressing schemes are, therefore, frequently adopted for LED displays. An active matrix addressing scheme for an organic polymer LED display device is shown in Figure 4, which illustrates four pixels of the display device. An active matrix driving scheme includes arrays of row and column address lines shown as X_1 and X_2, Y_1 and Y_2, in Figure 4. These address lines are in the form of thin conductive strips along which pixel selection signals and data signals can be fed to the pixels of the display device. Each pixel of the display device is provided with two transistors, shown as T_1 and T_2 in Figure 4. Further lines are also provided along which a supply voltage V_{ss} can be fed to the transistors at each pixel.

When it is desired to energise any particular pixel and so cause the LED located at that pixel to emit light, a select voltage pulse is supplied along a row address line, for example, row address line X_1 in Figure 4. This voltage pulse is received by the gate electrode G of transistor T_1 causing transistor T_1 to switch ON for the duration of the voltage pulse. Assuming that the top left pixel is required to emit light, a data signal is applied to the source of transistor T_1 which is ON. The data signal, shown as Data 1, is passed by transistor T_1 to the gate electrode of transistor T_2. Transistor T_1 operates as a switch, whereas transistor T_2

operates as a current driver for the organic LED, which is coupled to the supply V_{ss} via the transistor T_2. When operating as a current driver, the current at the drain of transistor T_2 will be a function of the magnitude of the data signal, Data 1. Hence, the current flowing through the organic LED, which determines the illumination intensity of the LED, can be controlled by variation of the signal Data 1.

The data signals are arranged so that the LED's always emit light during operation of the display and, therefore, lower operating voltages can be used. Hence, the use of the driver transistors at each pixel of the display enables the LED's to be operated at lower operating voltages, and hence, much higher efficiency. Figure 5 shows the typical operating efficiencies of LED displays when operated by active and passive matrix addressing schemes. The operating efficiency of the LED's is of paramount importance and is the primary reason why active matrix schemes are frequently adopted for LED displays. However, driver transistors usually comprise polysilicon transistors due to the higher carrier mobility provided by such devices. With organic polymer active matrix displays, as two driver transistors need to be provided for each LED pixel of the display, the transistor fabrication costs are relatively high because of the complexity of the fabrication techniques which must necessarily be adopted. These increased costs, particularly when the display area is made larger, negate the cost advantages provided by the organic polymer materials. Non-uniformity of transistor performance is also an issue. Again, this is particularly problematical for large area displays, because the large number of transistor drivers must be fabricated over the larger area of the display, giving rise to increased processing concerns and a reduction in the yield of fully functional transistor devices. For this reason 'redundant' driver transistors are usually provided, further increasing the cost of the display.

A further concern arises from the parasitic capacitance which exists between the driver lines to the driver transistors. In liquid crystal displays, the active liquid crystal material is located between the anode and cathode driver lines. The liquid crystal layer is usually in the range of 2 to 10 microns in thickness and, therefore, the parasitic capacitance arising between the driver line and counter common electrode is relatively small. However, for organic polymer LED displays, the organic polymer layer is very thin, typically a few hundred nanometres in thickness. Hence, the parasitic capacitance is relatively large in comparison to LCD displays and this parasitic capacitance limits the speed at which the displays may be

operated, which becomes particularly problematical as the display area increases. This is because it becomes necessary to address the display at a higher speed as the size of the display becomes larger in order to maintain the quality of the displayed image, but this gives rise to conflict because of the capacitance of the electrodes. Additionally, as the display size increases, the length, and hence the electrical resistance of the driver lines also increases, which again limits the speed at which the displays may be operated.

Therefore, it can be appreciated that for large area displays, difficulties arise whether active or passive driving schemes are adopted. For very large area displays, such as for example those used to display images in public places, it is known to combine a number of displays to provide the very large area display. However, each display making up part of such a very large area display is a separate display device. Whilst the use of a large number of display devices reduces the length of the driver lines in comparison to an equivalent size display made up of a single display device, each display device of the large area display nevertheless includes the relatively long address lines for addressing the active elements of the display. As such these continue to suffer from the concerns outlined above. Therefore, there is a significant need to provide an improved type of display device in which the above concerns are met.

According to a first aspect of the present invention, there is provided a display device comprising a plurality of display segments, each display segment having a display area of pixels defined by an array of active display elements arranged between a passive array of cathode electrodes and a passive array of anode electrodes supported by a first surface of a substrate, a first drive circuit for providing signals to the array of anode electrodes and a further drive circuit for providing signals to the array of cathode electrodes, the first and/or further drive circuits being arranged within the display area.

Advantageously, the first and further drive circuits may be arranged in wells provided on the first surface of the substrate, between the anode and the substrate, or in overlying relationship with the cathode electrodes.

Preferably, the substrate comprises a common substrate for at least a plurality of the display segments.

In a preferred arrangement, the active display elements comprise organic polymer light emitting diodes.

In a second aspect of the invention there is provided a method for fabricating a display device comprising a plurality of display segments, the method comprising providing a display area of pixels defined by an array of active display elements arranged between a passive array of cathode electrodes and a passive array of anode electrodes supported by a first surface of a substrate and arranging first and/or further drive circuits for respectively providing drive signals to the arrays of cathode and anode electrodes within the display area.

The active display elements may be fabricated from an organic polymer material which, advantageously, is deposited by an inkjet print head.

Embodiments of the present invention will now be described, by way of further example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a passive matrix addressing scheme for an LED display;

Figure 2 is a schematic representation showing how the LED's of the display shown in Figure 1 may be addressed;

Figure 3 is a plot showing variations of luminance and efficiency for a typical LED device;

Figure 4 is a schematic representation of an active matrix addressing scheme for an LED display;

Figure 5 is a plot showing the increase in efficiency which can be achieved by an active matrix addressing scheme in comparison to a passive matrix addressing scheme;

Figure 6 is a schematic cross-sectional representation of a liquid crystal display device

Figure 7 is a schematic representation of a display segment of a display device according to the present invention.

Figure 8 is a schematic representation of a prior art display device.

Figure 9 shows a display device in accordance with the present invention with drive circuits mounted on the back of the display device.

Figure 10 shows a partial cross-sectional view of a display segment having drive circuits located within wells located on a surface of a substrate.

Figure 11 shows a partial cross-sectional view of a display segment having drive circuits located on the front of the display segment.

For a liquid crystal display, the liquid crystal material, being a fluid material, must be contained between a substrate and a front plate or panel for the display. Hence, the addressing lines and the driver transistors (if an active matrix is used) are located between the substrate and front plate within the liquid crystal material itself, as shown in Figure 6. With such a construction, the liquid crystal pixels must, in practice, be driven from the edges of the display, otherwise, it becomes necessary to gain access to the addressing lines by providing holes through the first and rear panels of the display, which is not a practical proposition.

It follows that, with a liquid crystal display, as the size of the display area is increased, the length of the addressing lines will also increase, and the displays will suffer from the addressing problems described above, irrespective of whether an active or a passive matrix addressing scheme is adopted.

In an organic polymer LED, the active organic material may comprise an organic polymer material or an organic small molecule type material. For an organic polymer material, this is deposited in liquid form but once deposited onto the substrate and dry, is a solid and relatively flexible material. Small molecule type materials are deposited by evaporation but, likewise, these are also, once deposited, solid and relatively flexible

materials. Hence, for both organic polymer and small molecule type materials, the active organic material does not need to be retained on the substrate by the provision of the front plate, even though such a plate is provided in the finished display device to provide physical and environmental protection for the organic LED's. Therefore, with the present invention it has been realised that the organic LED's can be addressed from any position within the display and not just from the edge of the display. Furthermore, it has also been realised that, as the organic LED's can be addressed from any position, the active area of the display device can be sub-divided into many display segments, each provided with its own addressing array, giving rise to significant benefits in comparison to known arrangements for addressing schemes.

Irrespective of display size, a significant improvement in display performance can be realised because the length of the driver lines to the display elements can be significantly reduced in comparison to a conventional display device as the driver lines need to extend only within a segment and not the entire length or breadth of the display. This becomes particularly advantageous for a large area display device as the large display area can be constituted by a large number of small display segments, each having relatively short length addressing lines driven and extending only within each segment. This provides reduced resistance for the driver lines and the display intensity can, therefore, be improved because, for any given size of display, lower voltage drive pulses may be used enabling the LED devices to be operated in their optimum recombination zone, even for a large area display. Additionally, the addressing speed of the display can also be increased as there is very little parasitic capacitance between the arrays of co-operating anode and cathode electrodes composed of the relatively short addressing lines. As will be appreciated from the above description, the division of the display into a number of small segments with drive circuits arranged within the segments provides a display with improved contrast and resolution of displayed image. Furthermore, as it no longer becomes advantageous to adopt an active matrix addressing scheme, the fabrication of the display can be simplified significantly, giving rise to considerable cost benefits.

Moreover, with a conventional passive matrix addressing scheme with the display driven from a side edge, only one line of the display emits light at any one time because the lines are addressed sequentially during a frame period. In comparison, an active matrix

addressing scheme is beneficial because all of the pixels are arranged to emit light at all times. However, with the driver scheme of the present invention with the driver circuits arranged in the display segments of the display area, more than one segment can be addressed at any point in time. Hence, the segments can be arranged to emit light in a manner more akin to an active matrix addressing scheme, thereby increasing the luminance from the display.

Additionally, very large area displays can be achieved by combining a large number of display segments onto a common single substrate and as the organic polymer material is relative flexible, such large area displays can be fabricated using a continuous batch process in which a web of spoolable plastics material is fed past various processing stations to achieve display fabrication. Therefore, the cost benefits of organic polymer displays can be more easily realised by adopting a number of display segments, each with its own passive matrix addressing scheme and drive circuit.

Referring to Figure 7, a display segment 2 for a display device comprises a substrate 4 supporting an array of anode electrodes 6. A layer 8 of electroluminescent organic polymer material is provided over the anode electrodes 6. An array of cathode electrodes 10 is provided over the layer 8. The electroluminescent organic polymer material may comprise a conjugated polymer including, preferably, a fluorene group. When a voltage is applied between the anode elements and the cathode elements, such as between anode element 6a and cathode element 10a, a current flows through the polymer material located in that part of the layer 8 where the elements 6a and 10a overlap, shown as shaded area 12 in Figure 7. This causes the shaded area 12 to emit visible light and thus provide an active display element for the display. The shaded area 12 constitutes, therefore, in combination with the overlapping parts of the elements 6a and 10a, one of the pixels for the display segment.

The display segment 2 also includes a first drive circuit 14 for providing drive signals to the array of anode electrodes 6 through conductive tracks 16 and a further drive circuit 18 for providing drive signals to the array of cathode electrodes 10 via conductive tracks 20. The pixels of the segment 2 shown in Figure 7 in combination provide a display area 22 for the segment and this is delineated in Figure 7 by the bold dotted rectangle. It can be seen from Figure 7 that the drive circuits 14 and 18 are arranged within this display area of the display segment. Thus, the physical lengths of the arrays of anode and cathode electrodes 6, 10, which

form a passive matrix addressing system for the segment 2, can be kept to a minimum as they are addressed by drive circuits from within the segment itself.

It follows, therefore, that the electrical resistance of the electrodes as well as any parasitic capacitance which may be created between the anode and cathode electrodes, are significantly reduced in comparison to the anode and cathode electrodes of a conventionally addressed display device in which the equivalents of electrodes 6 and 10 would need to extend the entire length and breadth of the device. As described previously, this enables lower voltage drive signals to be adopted and the display elements, which constitute organic light emitting diodes, to be operated within their optimum recombination region, providing a display with much higher efficiency than known display devices.

Figure 8 illustrates schematically how a prior art known display device 24 may typically be configured. To ease explanation like reference numerals have been used in Figures 7 and 8 to signify the equivalent features of both devices. The display device 24 shown in Figure 8 is not configured as a plurality or number of display segments. The display area 22 is, therefore, constituted by a single unitary display having anode and cathode electrodes 6, 10 extending the entire length and breadth of the display area of the device. As such, the anode and cathode electrodes of the display device 24 are of significantly longer length than the anode and cathode electrodes of the display segment 2 shown in Figure 7, giving rise to the concerns as described previously. Furthermore, as will become apparent from the description following, because of their location within the active display area, the drive circuits 14 and 18 of the display segment of Figure 7 do not require to be encapsulated prior to mounting within the display area, as effective encapsulation can be carried out at a later stage as an integral step in the fabrication of the display device. In essence, therefore, the drive circuits of Figure 7 may be unencapsulated devices of very small physical size.

In contrast, the drive circuits 14 and 18 of the display device of Figure 8 are necessarily provided as fully encapsulated integrated circuits as they are located outside of the display area and wired to the respective anode and cathode electrode arrays through respective edges of the display. Hence, the drive circuits 14 and 18 of Figure 8 are much larger in physical size and significantly more expensive than the equivalent circuits of the display segment shown in Figure 7, because of the encapsulation and pin configuration necessary in

such devices to allow for the external wiring to the anode and cathode arrays. Therefore, it will be appreciated that by interconnecting a number of display segments 2, not only can the total display area be made larger for a given size of display device housing, because the drive circuits 14 and 18 are contained within and not at the sides of the display area, but also a lower cost, thinner or less bulky display device may be achieved as the drive circuits shown in Figure 7 may be provided as bare unencapsulated devices which are subsequently encapsulated by the provision of a thin encapsulation layer.

Figure 9 shows a display device 26 having a number of interconnected display segments 2. As with Figures 7 and 8, like reference numerals have been used to indicate like features of the display. It should be noted that Figure 9 shows the back view of the display, so in this embodiment, the drive circuits 14 and 18 of each display segment 2 are arranged between the array of anode elements 6 and the substrate 4 which, to assist clarity, is not shown in Figure 9. It should also be noted that whilst the display segment shown in Figure 7 has its own discrete substrate, in the embodiment shown in Figure 9 the display segments 2 are preferably provided on a substrate common to all of the segments in order to assist fabrication of the display device.

In the display device 26, the respective drive circuits 14 for the anode electrodes 6 of display segments 2 are interconnected by interconnects 28, and the cathode electrode drive circuits 18 are interconnected by interconnects 30. These interconnects serve, therefore, to combine the display segments 2 into the unitary display device 26. As can be seen from Figure 9, the anode and cathode electrodes 6, 10 are maintained as relatively short electrode strips, so although a large area display is provided, this is achieved without the need for relatively long anode and cathode electrodes, with their relatively high resistance and parasitic capacitance. In essence, this is made possible by effectively sub-dividing the passive addressing matrix to provide display segments, and locating the drive circuits 14, 18 within the display area of each segment. Furthermore, because the drive circuits 14, 18 are provided within each segment, the display area of the display device can be further increased to a very large size by including and interconnecting more display elements. But, once again this is achieved without the need to increase the length of the relatively short anode and cathode electrodes 6,10.

It should be appreciated that in the display device of Figure 9, the layer 8 of emissive organic polymer material (which is not visible in Figure 9) is disposed between the arrays of anode and cathode electrodes 6, 10. As such, the conductive tracks 20, which connect the drive circuits 18 on the rear side of the display to the cathode electrodes 10 on the front side of the display, must necessarily pass through the organic polymer layer 8. From Figure 9 it can be seen that the conductive tracks are arranged such that they pass through the layer 8 in spaces 32 between the anode electrodes 6 so as not to reduce the active area of the display device. Also, the organic polymer layer 8 is a relatively soft material, so it is relatively easy to provide such conductive tracks from one side to the other of the layer 8 during device fabrication. Alternatively, the conductive tracks may be provided by a series of pins, which may be provided on the drive circuit 18 and which pierce through the relatively soft and thin organic polymer layer. The same is also true for the display segment shown in Figure 7, where the anode drive circuit 14 provided on the front side of the display must be connected to the anode electrodes located under the organic polymer layer.

Figure 10 shows a further embodiment of the invention in which the drive circuits 14, 18 are located in wells 34 provided in the substrate 4. Because the drive circuits can be provided as unencapsulated integrated circuits the wells are of relatively small size and can be produced by any convenient process, such as by wet or dry etching, laser drilling, stamping or moulding of the substrate. The drive circuits can be interconnected by suitably positioned interconnects, similar to those shown in Figure 9.

Figure 11 shows a partial section through the display segment 2 shown in Figure 7 with the drive circuits 14, 18 mounted on the front side. As mentioned previously, because the drive circuits are provided within each display segment with its own passive array of anode and cathode electrodes, unencapsulated integrated circuit devices can be used for the drive circuits 14, 18, with subsequent encapsulation by a thin encapsulation layer. Such a layer 36 is shown in Figure 5. It will be appreciated that the encapsulation layer 36 can be extremely thin in comparison to the encapsulation packages used for stand alone integrated circuits as typically used for drive circuits in prior art displays and, hence, a very thin display can be achieved by adopting the present invention.

Usually, organic polymer LED displays are fabricated with a transparent anode and an opaque cathode, such that light emission occurs through a transparent substrate, such as glass. A display device incorporating a driver circuit configuration in accordance with the present invention may be fabricated in any configuration with regard to the transparency or opacity of the anode and cathode. For example, in the configuration shown in Figure 10, with the driver circuits 14 and 18 arranged in wells in the substrate, the anode may be made opaque and the cathode may be made transparent, in which case light emission occurs through the encapsulation layer 36. In this instance the transparent cathode may comprise, for example, a thin layer of Calcium (Ca) or Lithium Fluoride (LiF) with Indium Tin Oxide (ITO) and the opaque anode may comprise gold (Au) or platinum (Pt). Alternatively, in the configuration as shown in Figure 11, with the driver circuits 14 and 18 arranged in overlying relationship with the cathode, the anode may be made transparent and the cathode opaque, in which case, light emission occurs through the substrate, which can also be arranged to be a transparent material. In this case, the transparent anode may comprise, for example, Indium Tin Oxide or Zinc Oxide (Z_nO_2) and the opaque cathode may comprise a bilayer of Calcium/Aluminium (Ca/A1) or Lithium Fluoride/Aluminium (LiF/Al).

The layer 8 can be deposited by any suitable process but, being an organic polymer material, it may conveniently be deposited by ejecting the organic polymer material from an inkjet print head. Alternatively, the organic polymer may be deposited by spin coating. If the light emitting layer comprise a small molecule material, this may be deposited by evaporation.

With the present invention, a large number of display segments can be interconnected on a common substrate to form a large area display drive without the need to increase the voltage of the drive signals fed to the anode and cathode electrodes of the device. Hence, although the substrate 4 may be a rigid substrate, such as of glass, plastics or silicon, the present invention lends itself very favourably to the fabrication of a display device on a spoolable plastics substrate, thereby facilitating the efficient fabrication of very large area, high speed, high resolution displays with high efficiency.

In the embodiments described above, both the anode and cathode driver circuits are located within the display area of the display. However, for certain display devices, the anode or the cathode driver circuit may be located outside of the display area.

The foregoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the invention. For example, the invention has been described with reference to organic polymer LED displays but may also be used with reflective type liquid crystal displays. Furthermore, the driver circuits for the anode and cathode have been described as separate driver circuits. However, these driver circuits may be integrated into a unitary driver circuit, in which case both the anode and cathode may be driven by the unitary circuit. The present invention has been described with reference to an organic polymer material for use as the light emitting elements. However, small molecule materials may also be used to equal effect.

CLAIMS

1. A display device comprising a plurality of display segments, each display segment having a display area of pixels defined by an array of display elements arranged between a passive array of cathode electrodes and a passive array of anode electrodes supported by a first surface of a substrate, a first drive circuit for providing signals to the array of anode electrodes, and a further drive circuit for providing signals to the array of cathode electrodes, and wherein the first and/or further drive circuits are arranged within the display area.

2. A display device as claimed in claim 1, wherein the display elements comprise organic light emitting diodes.

3. A display device as claimed in claim 2, wherein the organic light emitting diodes comprise organic polymer material.

4. A display device as claimed in claim 2, wherein the organic light emitting diodes comprise small molecule material.

5. A display device as claimed in any one of the preceding claims, wherein the first and/or further drive circuits are arranged in wells provided on the first surface of the substrate.

6. A display device as claimed in any one of claims 1 or 4, wherein the first and/or further drive circuits are arranged between the anode electrodes and the substrate.

7. A display device as claimed in any one of claims 1or 4, wherein the first and/or further drive circuits are arranged in overlying relationship with the cathode electrodes.

8. A display device as claimed in any one of the preceding claims, wherein the drive circuit for providing signals to the electrodes disposed on an opposite side of the array of active display elements is provided with conductive tracks arranged to connect to the said electrodes on the opposite side in spaces between the pixels defined by the active display elements and the arrays of anode and cathode electrodes.

9. A display device as claimed in any one of claims 2, 3 or 4, or any one of claims 5, 6 or 7 when appendant to any one of claims 2, 3 or 4, wherein the drive circuit for providing signals to the electrodes disposed on an opposite side of the array of active display elements comprises a plurality of pins arranged to connect to the said electrodes on the opposite side through the organic light emitting diode display elements.

10. A display device as claimed in any one of claims 1 to 9, wherein the first and/or further drive circuits comprise unencapsulated integrated circuit devices.

11. A display device as claimed in any one of claims 8, 9 or 10, when appendant to claim 7, comprising an encapsulation layer for encapsulating the first and further drive circuits.

12. A display device as claimed in any one of the preceding claims, wherein the substrate comprises a common substrate for a plurality of the display segments.

13. A display device as claimed in claim 3, wherein the organic polymer comprises a conjugated polymer.

14. A display device as claimed in claim 13, wherein the conjugated polymer comprises a fluorene group.

15. A display device as claimed in any one of the preceding claims, wherein the substrate comprises a rigid substrate of glass, plastics or silicon.

16. A display device as claimed in any one of claims 1 to 14, wherein the substrate comprises a spoolable plastic material.

17. A display device as claimed in any one of the preceding claims, wherein the first and further drive circuits comprise an integrated drive circuit for providing signals to the anode and cathode electrodes.

18. A method for fabricating a display device comprising a plurality of display segments, the method comprising providing a display area of pixels defined by an array of display elements arranged between a passive array of cathode electrodes and a passive array of anode electrodes supported by a first surface of a substrate and arranging first and or further drive circuits within the display area for respectively providing drive signals to the passive arrays of cathode and anode electrodes.

19. A method as claimed in claim 18, comprising the step of fabricating the active display elements from an organic material.

20. A method as claimed in claim 19, comprising the step of fabricating the display elements from an organic polymer material.

21. A method as claimed in claim 20, comprising the step of fabricating the display elements from an organic small molecule material.

22. A method as claimed in any one of claims 18 to 21, comprising the step of arranging the first and further drive circuits in wells provided on the first surface of the substrate.

23. A method as claimed in any one of claims 18 to 21, comprising the step of arranging the first and further drive circuits between the anode electrodes and the substrate.

24. A method as claimed in any one of claims 18 to 21, comprising the steps of arranging the first and further drive circuits in overlying relationship with the cathode electrodes.

25. A method as claimed in any one of claims 18 to 24, comprising connecting the drive circuit for providing signals to the electrodes disposed on an opposite side of the array of display elements in spaces arranged between the pixels defined by the display elements and the arrays of anode and cathode electrodes.

26. A method as claimed in any one of claims 19 to 21, or any one of the claims 22, 23 or 24 when appendant to any one of claims 19 to 21, comprising providing the drive circuit for providing signals to the electrodes disposed on an opposite side of the array of display

elements with a plurality of pins arranged to connect to the said electrodes on the opposite side through the organic polymer light emitting diode display elements.

27. A method as claimed in any one of claims 18 to 26, comprising the step of providing the first and further drive circuits as unencapsulated integrated circuit devices.

28. A method as claimed in any one of claims 25, 26 or 27 when appendant to claim 24, comprising the step of providing an encapsulation layer over the first and further drive circuits.

29. A method as claimed in any one of claims 18 to 28, comprising the step of arranging the substrate to support a plurality of the display elements.

30. A method as claimed in claim 15, comprising the step of forming the organic material from a conjugated polymer.

31. A method as claimed in claim 30, wherein the conjugated polymer is selected to comprise a fluorene group.

32. A method as claimed in claim 20, 30 or 31, comprising the step of depositing the organic polymer material by an inkjet print head.

INVESTOR IN PEOPLE

Application No:	GB 0102434.8	**Examiner:**	Helen Edwards
Claims searched:	All	**Date of search:**	17 October 2001

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Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G5C: CHE

Int Cl (Ed.7): G02F: 1/1343 G09G: 3/32 H05B: 33/08, 33/12, 33/14

Other: Online database: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0978880 A (LG ELECTRONICS INC) See fig 1 and summary of invention	1, 2, 12, 15, 18, 19, 29

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.